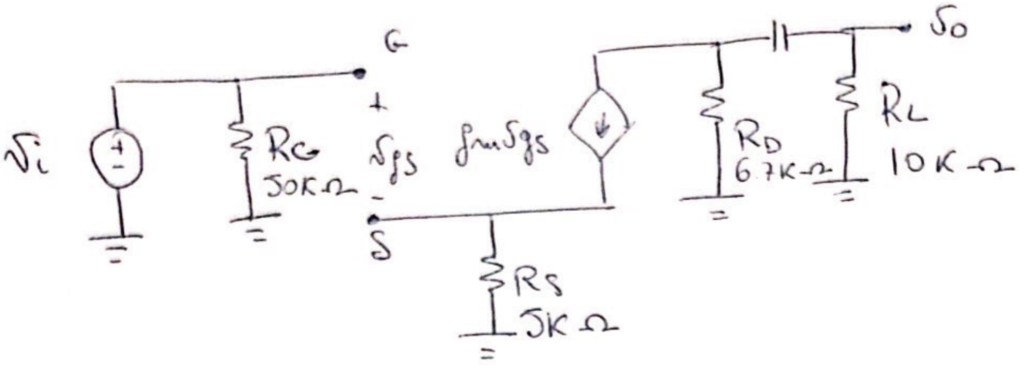
Corner frequencies of a CS amplifier with an output coupling capacitor

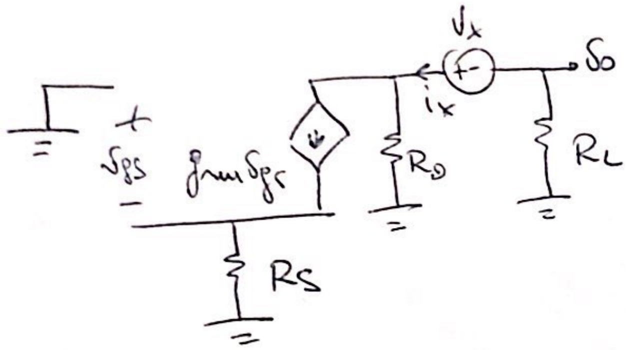
$$f_C = \frac{1}{2\pi \tau_C} \; ; \; \tau_C = C_C R_{eqC}$$

a) Sketch the low frequency small-signal circuit



b) Shut-down all the independent source and

c) replace the capacitor with a probe source V_x (i_x).



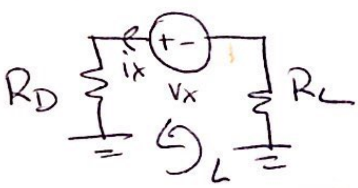
d) Calculate R_{eqC} as $\frac{V_x}{i_x}$

$$R_{eqC} = \frac{v_x}{i_x}$$

$$v_g = 0 \Rightarrow v_{gs} = -v_s = -R_S g_m v_s$$

$$v_s = R_S g_m v_s \Rightarrow v_s = 0$$

Thus the circuit become



KVL @ L: $-R_L i_x + v_x - R_D i_x = 0 \Rightarrow$

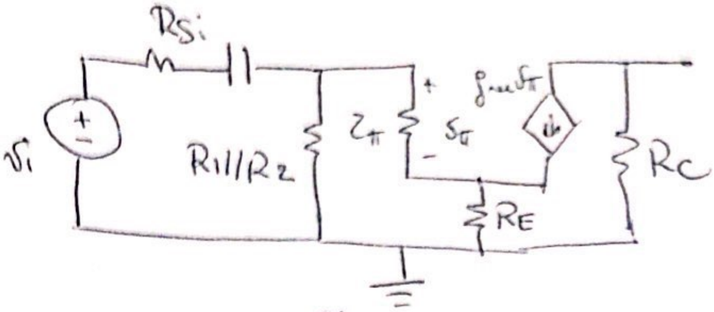
$$\Rightarrow \frac{v_x}{i_x} = R_D + R_L \Rightarrow R_{eqC} = R_D + R_L$$

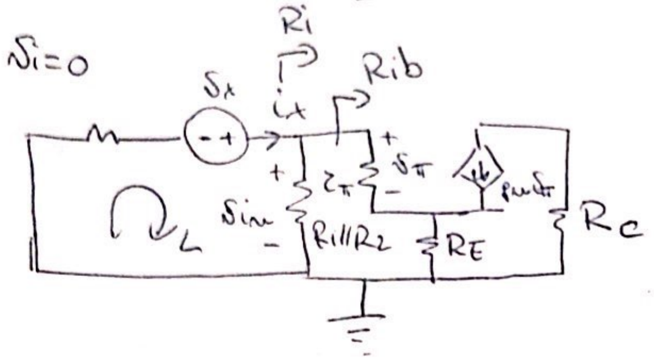
$$f_C = \frac{1}{2\pi (R_D + R_L) C_C}$$

Corner frequencies for a CE amplifier with an input coupling capacitor and a load capacitor.

$$f_L = \frac{1}{2\pi\tau_c} = \frac{1}{2\pi R_{eqC} C_c} \quad ; \quad f_H = \frac{1}{2\pi\tau_L} = \frac{1}{2\pi R_{eqL} C_L}$$

f_L





$$R_{eq_C} = \frac{v_x}{i_x}$$

KVL @L

$$v_x = R_{si} i_x + R_i i_x$$

$$R_{eqC} = \frac{v_x}{i_x} = R_{si} + R_i$$

$$R_i = R_1 // R_2 // R_{ib}$$

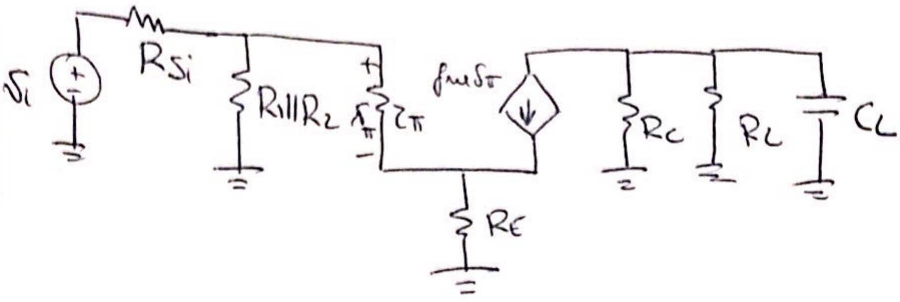
$$R_{ib} = r_\pi + R_E(1+\beta)$$

$$R_{eq}C = R_{si} + [R_1//R_2 // [r_\pi + R_E(1+\beta)]]$$

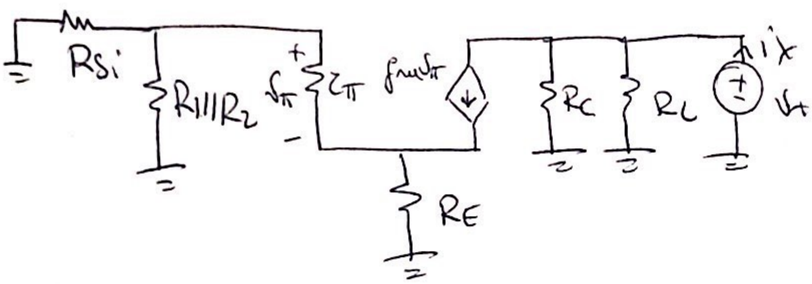
$$\tau_c = C_c\{R_{si} + R_1//R_2 // [r_\pi + R_E(1+\beta)]\}$$

$$f_c = f_L = \frac{1}{2\pi C_c \{R_{Si} + [R_1\|R_2 \,//\, [r_\pi + R_E(1+\beta)]]\}}$$

$$f_H = \frac{1}{2\pi \tau_L} = \frac{1}{2\pi C_L R_{eqL}}$$



$v_i = 0$

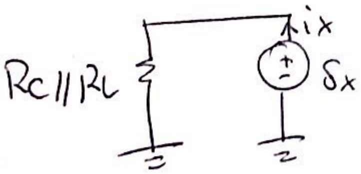


$v_\pi = r_\pi i_{r\pi} =$

$= r_\pi \cdot g_m v_\pi \cdot \dfrac{R_E}{R_1\|R_2\|R_{Si} + r_\pi + R_E}$

Hence $v_\pi = 0$ and $g_m v_\pi = 0$.

As the dependent current source is determining the voltage drop that controls the current source, $g_m v_\pi = 0$. Thus, the circuit reduces to



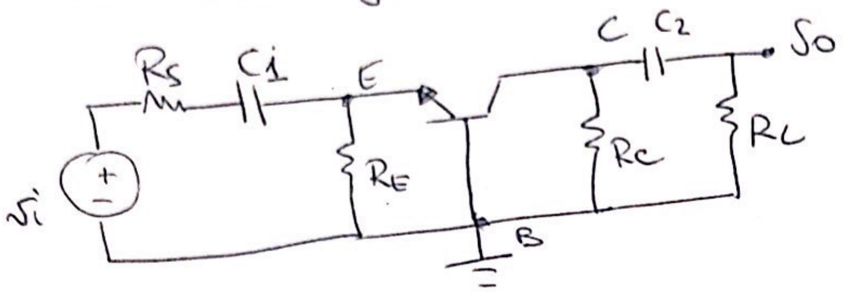
$R_{eqL} = R_C // R_L$

$$f_H = \frac{1}{2\pi C_L (R_C\|R_L)}$$

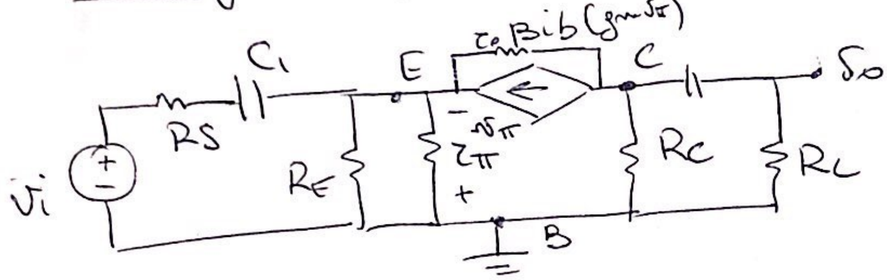
Corner frequency of a circuit with 2 coupling capacitors.

$f_L = \frac{\omega_L}{2\pi}$ $\quad \omega_L \simeq \sum_{i=1}^{n} \frac{1}{R_{iL} C_i}$ where n is the number of capacitors affecting the frequency response at low frequency and $R_{iL} C_i$ is the time constant associated with capacitor C_i when all other capacitors are replaced with short circuits

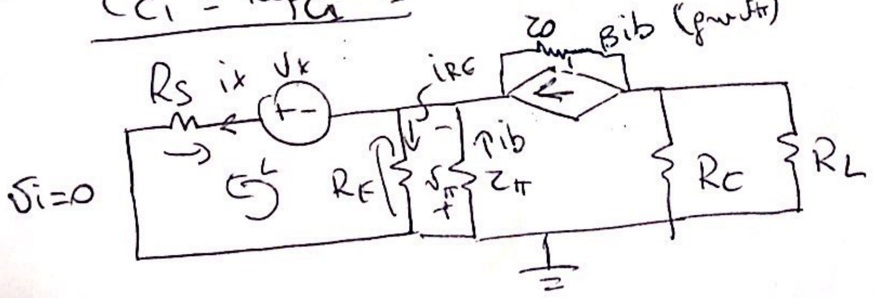
Low-frequency AC circuit



Low-frequency Small-Signal circuit



$\tau_{C_1} = R_{eq_{C_1}} C_1$



$R_{eq_{C_1}} = \frac{v_x}{i_x}$ see lecture 15

$R_{eq_{C_1}} = R_S + R_{inCB} \simeq$

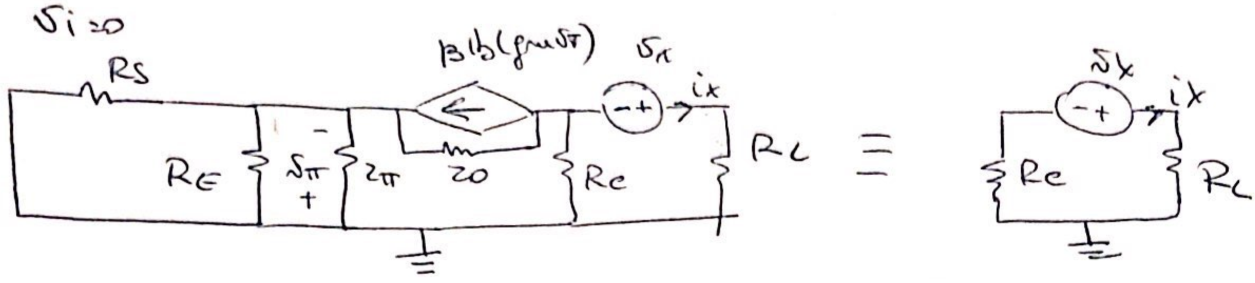
$\simeq R_S + \left(R_E \,//\, \frac{r_\pi}{1+\beta}\right)$

see lecture 15

$$\tau_{C_1} = \left[R_S + \left(R_E \,//\, \frac{r_\pi}{\beta+1}\right)\right] C_1$$

$$\tau_{C_2} = R_{eq_{C_2}} C_2$$

$v_i = 0$



$$R_{eq_{C_2}} = \frac{v_x}{i_x} = R_L + R_{out\,CB} \simeq R_L + R_C$$

see lecture 15   see lecture 15

$$\tau_{C_2} = C_2 \left(R_L + R_C \right)$$

$$\omega_L \simeq \frac{1}{\left[R_S + R_E \parallel \frac{r_\pi}{\beta + 1} \right] C_1} + \frac{1}{\left(R_L + R_C \right) C_2}$$

The smallest capacitor will dominate the low frequency response as all resistors have comparable values, typically.